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# ORGANOCHLORINES AND MERCURY IN PEREGRINE FALCON EGGS FROM WESTERN NORTH CAROLINA

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In North Carolina, Peregrine Falcons (*Falco peregrinus anatum*) were historically regarded as an uncommon breeding bird in the western mountains (Pearson et al. 1919, 1942) prior to their contaminant-induced extirpation in the eastern U.S. (Hickey 1969). Surveys in the early 1970s indicated peregrines no longer bred in North Carolina or at any historical nest sites east of the Mississippi River (Fyfe et al. 1976). Efforts to restore peregrines to the breeding bird fauna of North Carolina included protection of nesting habitat and the introduction of 81 young peregrines, produced in captivity by the Peregrine Fund, Inc. and private breeders (Barclay 1988), at seven sites between 1984–91. Introduced birds first bred in 1987 and successfully so in 1988. One to five pairs have bred each year producing a mean of 0.0–2.5 young per occupied territory and an average of 0.81 young per occupied territory from 1987–95 (Boynton and Currie 1993, C. McGrath pers. comm.).

Peregrine Falcons in western North Carolina occupy a portion of the Southern Appalachian recovery region; an objective of the recovery plan is the establishment of 20–25 nesting pairs in this region (U.S. Fish and Wildlife Service [hereafter USFWS] 1979, 1991), a level that has not been attained. Although contaminants were not suspected to be limiting productivity, no analyses had been performed on this new population prior to this assessment. Our objectives were to quantify organochlorine and mercury concentrations and shell thickness from western North Carolina peregrine eggs and to evaluate their significance relative to reproduction.

## METHODS

Between 1990–93, five Peregrine Falcon eggs were collected from four clutches in three breeding territories after they were either incubated past term or abandoned. Eggs were stored frozen until harvested into acid-rinsed and solvent-rinsed glass jars for analyses.

The USFWS Patuxent Analytical Control Facility analyzed for 20 organochlorine compounds and mercury. Organochlorine analyses were by gas-liquid chromatography with peak confirmation of p,p′-DDE by gas chromatography/mass spectrometry under methods adapted from Cromartie et al. (1975). Mercury determination was performed by cold vapor atomic absorption spectrophotometry as described by the Joint Mercury Residues Panel (1961).

The lower limit of detection was 0.01 ppm wet weight for organochlorines and 0.04 ppm wet weight for mercury. A procedural blank indicated no background contamination of analytical equipment or reagents. Results of duplicate analyses and spike recoveries for mercury (104%), DDT metabolites (54.7–107%), lindane (69.6%), and chlordane metabolites (65.1–89.8%) were within acceptable ranges for method precision and accuracy. Residues reported here were not adjusted for recoveries.

We used a regression equation for American Kestrel (*Falco sparverius*) eggs to estimate egg volume (Wiemeyer et al. 1986). Because samples had dehydrated from exposure and refrigeration, we adjusted all residue concentrations for moisture loss using egg weight to volume ratios and assuming a specific gravity of 1.0 (Stickel et al. 1973). All contaminant concentrations are reported as parts per million (ppm) fresh wet weight. Contaminant concentrations for the two eggs collected in 1991 from Whiterock Cliff were averaged prior to calculating geometric means. Consequently, geometric means are based on clutches ($N = 4$) rather than individual eggs ($N = 5$).

Eggshell thicknesses of the five specimens and shell fragments from four additional nests were determined with a Federal Model 35 bench comparator thickness gauge at the Western Foundation for Vertebrate Zoology. At least 10 measurements of each sample were made for each mean reported.

## RESULTS AND DISCUSSION

DDE, a metabolite of DDT, was considered causative in the extirpation of the Peregrine Falcon after it was found that DDE-induced eggshell thinning of around 20% was invariably associated with declining populations (Risebrough and Peakall 1988). Corresponding DDE residues

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Table 1. Concentrations of mercury (Hg) and organochlorines measured in eggs of North Carolina Peregrine Falcons. Concentrations are ppm fresh wet weight and corresponding shell thicknesses are in mm.

| LOCATION AND YEAR | SHELL THICKNESS | Hg | p,p′ DDE | TOTAL DDT[a] | TOTAL CHLORDANE[b] | DIELDRIN | LINDANE |
|---|---|---|---|---|---|---|---|
| Chimney Rock Rutherford County 1993 | 0.332 | 0.14 | 1.47 | 1.70 | 0.50 | 0.12 | 0.02 |
| Looking Glass Rock Transylvania County 1990 | 0.329 | 0.07 | 5.72 | 6.13 | 1.95 | 0.42 | 0.03 |
| Looking Glass Rock Transylvania County 1992 | 0.386 | 0.11 | 3.96 | 4.26 | 1.04 | 0.18 | 0.01 |
| Whiterock Cliff Madison County 1991 | 0.328 | 0.05 | 5.14 | 5.70 | 1.32 | 0.54 | 0.02 |
| Whiterock Cliff Madison County 1991 | 0.321 | 0.10 | 2.64 | 3.03 | 1.71 | 0.66 | 0.01 |

[a] Total DDT defined here as summed o,p′–DDD, o,p′–DDE, o,p′–DDT, p,p′–DDD, p,p′–DDE, and p,p′–DDT.
[b] Total chlordane defined here as sum of alpha chlordane, cis-nonachlor, gamma chlordane, heptachlor epoxide, oxychlordane, and trans-nonachlor.

of 15–20 ppm have been associated with population level average eggshell thinning of this magnitude (Peakall and Kiff 1988). The geometric mean concentration of p,p′-DDE in North Carolina Peregrine Falcon clutches was 3.37 ppm (Table 1). Total metabolites of DDT ranged from 1.70–6.13 ppm with a geometric mean concentration of 3.73 ppm. These DDE concentrations are well below those associated with population declines (Peakall and Kiff 1988).

Arithmetic mean eggshell thicknesses were 0.339 mm for the five whole eggs and 0.334 mm when the shell fragments from four additional nests were included. Assuming a pre-1947 eggshell thickness for eastern Peregrine Falcons of 0.360 mm (Burns et al. 1994), the values reported here are approximately 7% thinner than normal, pre-DDT era eggshells. Peakall and Kiff's (1988) summary of thinning data indicate that extirpated or declining Peregrine Falcon populations occurred whenever mean population-level eggshell thinning exceeded 17% (except for intensively managed populations). Fyfe et al. (1988) suggested 14.5% thinning as a minimum estimate of the threshold below which there is no appreciable effect on peregrine productivity. Since the stock for the restored eastern Peregrine Falcon population was derived from several sources, eggshell thickness comparisons must necessarily be approximate.

The geometric mean concentration of total chlordane components and metabolites (1.11 ppm) was composed primarily by oxychlordane (0.30 ppm) and heptachlor epoxide (0.22 ppm). Peakall et al. (1990) considered ≥1.5 ppm heptachlor epoxide to be critical for producing adverse effects in peregrine eggs.

Dieldrin levels in raptors were reviewed by Peakall et al. (1990); they derived an egg screening value for determining adverse effects in Peregrine Falcons of 1–4 ppm. Peakall (1996) reported a "no-observed-effect" level of dieldrin at 0.7 ppm. North Carolina Peregrine Falcon eggs were well below this range with a geometric mean of 0.27 ppm.

Lindane has been used to control balsam wooly adelgid (*Adelges piceae*) infestation of fraser fir (*Abies fraseri*) in western North Carolina. The geometric mean concentration of lindane in our samples was 0.02 ppm. Lindane has not been associated with avian impairment in the wild, and levels well above those reported here have been detected in bird eggs without any apparent effects (Wiemeyer 1996).

Mercury has been shown to cause mortality and reproductive impairment in wild birds (Eisler 1987). The geometric mean mercury concentration of 0.10 ppm in North Carolina Peregrine Falcon eggs is below estimates of 0.5–1.0 ppm used by others as screening values for reproductive effects on peregrines (Peakall et al. 1990) and other raptors (Bowerman et al. 1995).

The geometric mean concentration of DDE in peregrine eggs from the Southern Appalachian recovery region was approximately half that reported for eggs from the mid-Atlantic and northeastern U.S. (Gilroy and Barclay 1988, Burns et al. 1994). The lower DDE concentrations in peregrine eggs from the Southern Appalachian

recovery region may be due to different prey preferences. Preliminary data indicate that western North Carolina peregrines depend largely on resident birds, particularly Rock Doves (*Columba livia*), Mourning Doves (*Zenaida macroura*), Northern Flickers (*Colaptes auratus*), and Blue Jays (*Cyanocitta cristata*) (Boynton and Currie 1993). Additional documentation of prey preferences is ongoing.

Factors possibly limiting productivity include nest predation, inclement weather, inexperience, poor food supply, and human disturbance (Boynton and Currie 1993). While a larger data set is advisable before ruling out pollutant effects, our current data suggest that environmental contaminants are not limiting productivity of peregrines in the Southern Appalachian recovery region. The USFWS (1995) has indicated its intention to remove the Peregrine Falcon from the list of Endangered and Threatened Species. These data may serve as a baseline in future monitoring of the Southern Appalachian population which may be a requirement following delisting.

RESUMEN.—Concentraciones de pesticidas organoclorados y mercurio fueron encontrados en huevos colectados de cinco halcones peregrinos de una población reestablecida en el noroeste de Carolina. Las concentraciones de la media geométrica de p,p′ DDE (3.37 ppm en peso fresco), total de metabolitos de chlordane (1.11 ppm), dieldrin (0.27 ppm), lindano (0.02 ppm), y mercurio (0.10 ppm) estaban generalmente por debajo de los niveles asociados al fracaso reproductivo. Los 0.334 milímetros de la media aritmética del grueso de la cáscara de los huevos, fué del 7% mas delgada de lo normal encontrado en la "pr–era" del DDT de la población original del este de Estados Unidos.

[Traducción de César Márquez]

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LITERATURE CITED

BARCLAY, J.H. 1988. Peregrine restoration in the eastern United States. Pages 549–558 *in* T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White [EDS.], Peregrine Falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise, ID U.S.A.

BOWERMAN, W.W., J.P. GIESY, D.A. BEST AND V.J. KRAMER. 1995. A review of factors affecting productivity of Bald Eagles in the Great Lakes region: implications for recovery. *Environ. Health Perspect.* 103:51–59.

BOYNTON, A.C. AND R. CURRIE. 1993. Productivity of reintroduced Peregrine Falcons in western North Carolina. *Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies* 47:386–393.

BURNS, S.A., W.M. JARMAN, T.J. CADE, L.F. KIFF AND B J WALTON. 1994. Organochlorines and eggshell thinning in Peregrine Falcon *Falco peregrinus* eggs from the eastern United States, 1986–1988. Pages 709–716 *in* B.-U. Meyburg and R.D. Chancellor [EDS.], Raptor conservation today. Proceedings of the IV world conference on birds of prey and owls. Pica Press, London, U.K.

CROMARTIE, E., W.L. REICHEL, L.N. LOCKE, A.A. BELISLE, T.E. KAISER, T.G. LAMONT, B.M. MULHERN, R.M. PROUTY AND D.M. SWINEFORD. 1975. Residues of organochlorine pesticides and polychlorinated biphenyls and autopsy data for Bald Eagles, 1971–72. *Pest. Monit J.* 9:11–14.

EISLER, R. 1987. Mercury hazards to fish, wildlife, and invertebrates: a synoptic review. USFWS Biol. Rep. 85(1.10). U.S. Fish Wildl. Serv., Laurel, MD U.S.A

FYFE, R.W., S.A. TEMPLE AND T.J. CADE. 1976. The 1975 North American Peregrine Falcon survey. *Can. Field Nat.* 90:228–273.

———, R.W. RISEBROUGH, J.G. MONK, W.M. JARMAN, D.W. ANDERSON, L.F. KIFF, J.L. LINCER, I.C.T. NISBET, W. WALKER, II AND B.J. WALTON. 1988. DDE, productivity, and eggshell thickness relationships in the genus *Falco*. Pages 319–335 *in* T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White [EDS.], Peregrine Falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise, ID U.S.A.

GILROY, M.J. AND J.H. BARCLAY. 1988. DDE residues and eggshell characteristics of reestablished peregrines in the eastern United States. Pages 403–411 *in* T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White [EDS.], Peregrine Falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise ID U.S.A.

HICKEY, J.J. 1969. Peregrine Falcon populations: their biology and decline. Univ. Wisconsin Press, Madison, WI U.S.A.

JOINT MERCURY RESIDUE PANEL. 1961. Recommended methods of analysis of pesticide residues in food stuffs. *Analyst* 86:608–614.

PEAKALL, D.B. 1996. Dieldrin and other cyclodiene pesticides in wildlife. Pages 73–97 *in* W.N. Beyer, G.H. Heinz and A.W. Redmon-Norwood [EDS.], Environmental contaminants in wildlife: interpreting tissue concentrations. Lewis Publishers, Boca Raton, FL U.S.A.

——— AND L.F. KIFF. 1988. DDE contamination in peregrines and American Kestrels and its effect on reproduction. Pages 337–350 *in* T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White [EDS.], Peregrine Falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise, ID U.S.A.

———, D.G. NOBLE, J.E. ELLIOT, J.D. SOMERS AND G. ERICKSON. 1990. Environmental contaminants in Canadian Peregrine Falcons, *Falco peregrinus*: a toxicological assessment. *Can. Field Nat.* 104:244–254.

PEARSON, T.G., C.S. BRIMLEY AND H.H. BRIMLEY. 1919. Birds of North Carolina. North Carolina geologic and economic survey. Vol. IV. Edwards and Broughton Printing Co., Raleigh, NC U.S.A.

———. 1942. Birds of North Carolina. North Carolina Department of Agriculture. Bynum Printing Co., Raleigh, NC U.S.A.

RISEBROUGH, R.W. AND D.B. PEAKALL. 1988. The relative importance of several organochlorines in the decline of Peregrine Falcon populations. Pages 449–462 *in* T.J. Cade, J.H. Enderson, C.G. Thelander and C.M. White [EDS.], Peregrine Falcon populations: their management and recovery. The Peregrine Fund, Inc., Boise, ID U.S.A.

STICKEL, L.F., S.N. WIEMEYER AND L.J. BLUS. 1973. Pesticide residues in eggs of wild birds: adjustment for loss of moisture and lipid. *Bull. Environ. Contam. Toxicol.* 9: 193–196.

U.S. FISH AND WILDLIFE SERVICE. 1979. Eastern Peregrine Falcon recovery plan. Washington, DC U.S.A.

———. 1991. First update of Peregrine Falcon (*Falco peregrinus*), eastern population, revised recovery plan. Newton Corner, MA U.S.A.

———. 1995. Endangered and threatened wildlife and plants; advance notice of a proposal to remove the American Peregrine Falcon from the list of endangered and threatened wildlife. *Federal Register* 60: 34406–34409.

WIEMEYER, S.N. 1996. Other organochlorine pesticides in birds. Pages 99–115 *in* W.N. Beyer, G.H. Heinz and A.W. Redmon-Norwood [EDS.], Environmental contaminants in wildlife: interpreting tissue concentrations. Lewis Publishers, Boca Raton, FL U.S.A.

———, R.D. PORTER, G.L. HENSLER AND J.R. MAESTRELLI. 1986. DDE, DDT + dieldrin: residues in American Kestrels and relations to reproduction. USFWS, Fish Wildl. Tech. Rep. 6. Washington, DC U.S.A.

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# IMPORTANCE OF BIRDS AND POTENTIAL BIAS IN FOOD HABIT STUDIES OF MONTAGU'S HARRIERS (*CIRCUS PYGARGUS*) IN SOUTHEASTERN SPAIN

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KEY WORDS: *Montagu's Harrier*; Circus pygargus; *diet*; *mediterranean*.

Methods used to study the diets of raptors include the analysis of pellets, stomach contents, prey remains in nests or under perches, and direct observation of prey delivered to nests. In many species, including harriers (*Circus* spp.), analysis of prey remains only appears to underestimate the proportion of smaller prey and overestimate the occcurence of large prey (Schipper 1973, Simmons et al. 1991, Mañosa 1994, Real 1996). Several researchers have studied the diet of Montagu's Harrier (*Circus pygargus*) during the breeding season (Pérez-Chiscano and Fernández-Cruz 1971, Pérez-Chiscano 1974, Corbacho et al. 1995, Thiollay 1968, Helmich 1986), on migration (Castroviejo 1969), and while wintering (Cramp and Simmons 1980, Cormier and Baillon 1991). Extensive studies of their breeding diet in Spain (Hiraldo et al. 1975, Arroyo 1997), Holland and France (Schipper 1973), and Britain (Underhill-Day 1993) indicate that small birds and mammals are important prey in northern and central Europe, whereas in southern Europe invertebrates appear to be numerically important, together with small birds (Underhill-Day 1993, Hiraldo et al. 1975). The goal of our study was to assess the importance of birds in the diet of Montagu's Harriers and to test how different study methods affect the results of such a food habits study.

## STUDY AREA AND METHODS

The diets of three pairs of Montagu's Harriers breeding in a wadi or "rambla" in a mediterranean semiarid region in southeastern Spain (Suárez et al. 1996) were studied during 1995. Ajauque is a small wetland located in the most arid sector (average annual rainfall = 30 cm) of Murcia in southeastern Spain. Ajauque rambla drains an impermeable watershed of sedimentary marls. In arid and semiarid lands of the region, ramblas are more productive than surrounding lands owing to their vegetation that consists mainly of reeds (*Phragmites australis*) and halophytic plants. The Ajauque rambla is part of a protected